Bond strength and tensile strength of surface treated resin teeth with microwave cured and heat cured acrylic resin denture base: An in-vitro study

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Abstract

Purpose: The study compared the effect of pre-processed surface treatment such as sand blasting and grinding of ridge lap area of the acrylic teeth on the tensile strength and bond strength of the permanent denture base fabricated with different curing techniques.

Materials and methods: Ridge lap surface areas of the acrylic maxillary anterior teeth were treated with sandblasting and grinding procedure. Specimens were fabricated and processed with conventional heat cured, microwave cured and self cured techniques. Specimens were subjected to bond strength and tensile strength testing.

Results: Sandblasting in all type of curing possessed higher bond and tensile strength. Grinding method yielded higher bond and tensile strength compared to control groups.

Conclusion: It is recommended sandblast the ridge lap area of the acrylic denture teeth prior to denture base processing.

KEYWORDS: Bond strength; conventional cure; microwave cure; sand blasting

Introduction

Adequate bonding of acrylic resin teeth to denture base resin is necessary because it increases the strength and durability of the denture since the teeth become integral part of the prosthesis. The most common type of denture failure occurs between an acrylic resin tooth and acrylic resin denture base, accounting for approximately 33% of failure.

Failure of acrylic denture tooth adherence has also been reported in implant supported overdentures. There is reason to believe that this problem must be considered a major concern in denture fabrication[1]. However, de-bonding of acrylic teeth denture base remains a major problem in Prosthodontic practice.

It has been estimated that between 22% and 30% of denture repairs involve tooth de-bonding, usually in the anterior region of the denture. This detachment may be attributed to a lesser ridge lap surface areas available for bonding and the direction of the stresses encountered during function.

Two processes affect the achievement of a bond between the acrylic teeth and denture base resin: (i) The polymerizing denture base resin must come into physical contact with the denture tooth resin and (ii) The polymer network of denture base resin must react with the acrylic tooth polymer to form inter woven polymer network[2].

Stress of magnitude 74 - 90 MPa occurs at the interface which is in excess of the recommendation by the National Standards for adhesive bond strength (American National standard: 3 1 MPa and Australian National Standard: 32 MPa). In recent years there is an increase in the usage of implant supported overdentures. This has not only increased the biting forces of such dentures but also increased the mechanical failure of the prosthesis. Inadequate thickness of acrylic resin in the anterior segment of a denture as a result of the dimensions of bar and clip attachments can lead to fracture of the denture and teeth de-bonding from the base[3]. Several studies have been conducted to enhance the retention of acrylic teeth with denture base. Commercial and experimental bonding agents were evaluated for tooth retention when applied to heat cured and visible light-cured (VLC) resin. A significant increase in shear bond strength was found.[4] Thermocycling effects and shear bond strength of acrylic resin teeth to denture base resins revealed that thermocycling reduced the bond strength between the teeth and the acrylic resin denture base. [3]

The surface treatment with different regimens of microblasting, coating with a solvent based adhesive showed that microblasting the tooth ridge lap surface seemed to have a major and significant contribution to establishing a satisfactory interfacial bonding[5]. Contamination with wax has been suggested as the major cause for bond failure between teeth and denture base resins.

Heat activated resins produced a higher bond strength than the microwave cured, visible light-cure acrylic resins, poured type or self cure acrylic resins. [6] The bond strength of acrylic resin teeth with and without retention grooves processed onto standard and high-impact denture base resin was investigated. Vertical retention grooves enhanced bond strength.

A study demonstrated a highly significant difference between the bonds of the three brands of abrasion resistance plastic denture teeth and the control tooth[7]. Ridge lap was reduced by 1mm to aid in the penetration of the denture base acrylic monomer. Retention grooves to the ridge lap surface of the plastic teeth has been shown to require greater force to separate them from the acrylic resin base[8]. Dichloromethane has been applied in a study on the denture teeth ridge lap area prior to denture base processing.[9] Composite has also been used to modify acrylic resin denture teeth. [10]

MATERIALS AND METHODS

A metal former (70x 25mm) of the design used in the ANSI/ADA Specification which incorporates a trough of 5 mm wide by 1.5 mm deep for mounting the teeth was used in this study. Total of 216 acrylic maxillary anterior teeth from canine to canine were used. In order to keep uniform surface for bonding, a positioning silicone device with an open window (5x5 mm) was constructed (Figure 1). 72 sets of acrylic teeth were treated by sandblasting of ridge lap surface of 25mm^2 using the silicone device. Sandblasting was done with abrasion equipment and aluminium oxide particles of 250 microns size under 5 kg /cm^2 of pressure for 5 seconds.

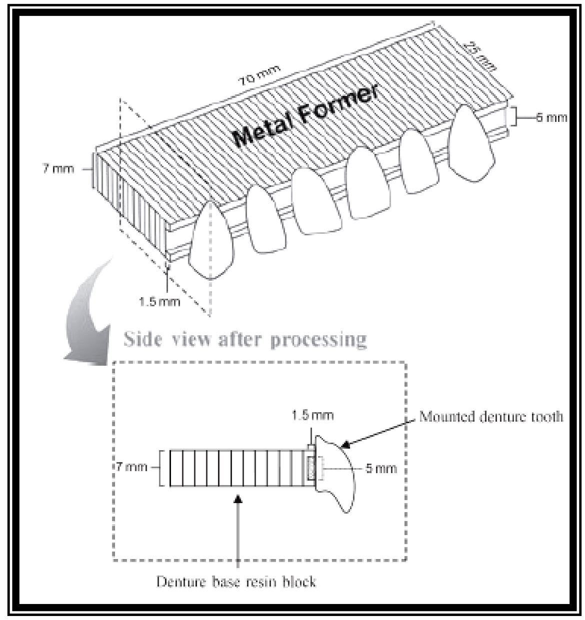

Figure 1:DESIGN OF THE METAL FORMER

72 sets of acrylic teeth were treated by grinding over the ridge lap surface within the area of 25mm^2 using silicone positioning device. Grinding was done with a tungsten carbide bur at a speed of 15,000 rpm. Remaining 72 sets of teeth without grinding or sandblasting treatment were used as control. Samples were cleaned in a distilled water bath for 10 minutes to remove any trapped residue and dried. There were three groups of test specimens and each group had 72 sets of anterior teeth. 72 sets of each specimen were divided into three subgroups with 24 sets each for processing with three types of denture processing technique (Figure 2).

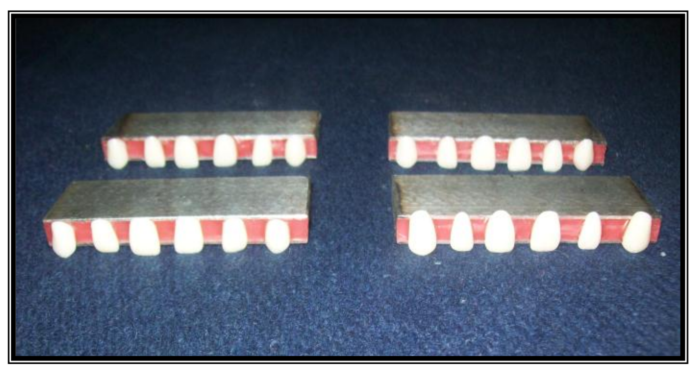

Figure 2: TEETH WAX-UP IN THE METAL FORMER

The three processing techniques used were conventional heat cure, self cure and microwave cure technique. Total 24 sets of teeth were used for each processing technique. Six anterior teeth were mounted on the metal former using base plate wax. After mounting specimens were invested in a conventional denture base flask and the microwave flask respectively and dewaxing was followed. Specimens were processed in a microwave oven for 4 minutes at 500 Watts and bench-cooled for 1 hour before deflasking (Figure 3).

Figure 3: MICROWAVE OVEN

Similarly, heat-polymerized specimens were processed in a heat curing unit for 9 hours at 74^0 C and bench-cooled for 1 hour before deflasking. Specimens were deflasked and the gross adhering of stone was removed with hand instruments. Gross blebs were removed with a slow speed hand piece and acrylic bur. Specimens were then stored in distilled water. All specimens were subjected to bond strength and tensile strength testing in a Hounsfield Universal Testing Machine (H10K). Metal jig was fabricated to hold the specimen during application of load (Figure 4). Machine used a direct pull on the incisal portion of the lingual surface in a labial direction at height above the denture base resin bar with a crosshead speed of 5mm/ min.

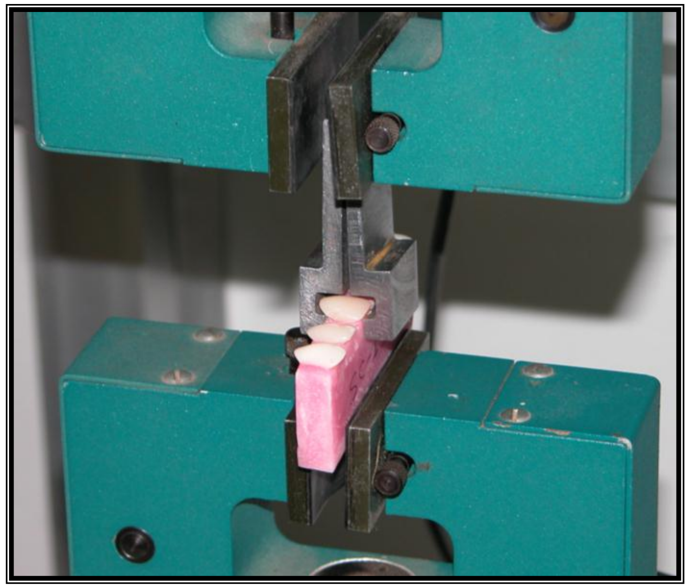

Figure 4: SAMPLE HELD IN HOUNSFIELD U T M

RESULTS

The present study was designed to compare the effect of pre-processed surface treatment such as sand blasting on tensile strength and bond strength of the denture base resin fabricated with different techniques (Table I,II). From the ANOVA tables (Table III, IV) we notice that treatment has a significant difference between the different groups influencing bond strength and tensile strength ($P < 0.001$). Also, there is a significant difference between the different curing resins ($P < 0.001$). The interaction (joint effect) of treatment group and curing on bond strength and tensile strength is also found to be significant ($P < 0.001$).

Table I : The mean, standard deviation and median of bond strength recorded during different surface treatments and various processing technique in Mpa

	Processing technique	Mean	Standard Deviation	Median	Minimum	Maximum
Control	Heat Cure Resin	42.84	1.46	42.70	40.50	45.50
	Microwave Cure Resin	42.71	1.04	42.65	40.90	44.10
	Self Cure Resin	32.59	1.14	32.60	30.50	34.50
Grinding	Heat Cure Resin	47.31	1.29	47.10	45.10	49.90
	Microwave Cure Resin	42.83	0.98	42.90	40.90	45.00
	Self Cure Resin	33.95	0.67	33.90	32.90	35.10
Sand Blasting	Heat Cure Resin	53.07	1.46	53.40	50.10	54.90
	Microwave Cure Resin	46.47	0.90	46.15	45.30	48.20
	Self Cure Resin	36.89	0.82	36.80	35.80	38.50

Table II: The mean, standard deviation and median of tensile strength recorded during different surface treatments and various processing technique in Mpa.

Treatment	Processing technique	Mean	Standard Deviation	Median	Minimum	Maximum
Control	Heat Cure Resin	12.05	1.09	11.90	10.10	13.90
	Microwave Cure Resin	7.93	0.89	7.85	6.30	9.80
	Self Cure Resin	2.90	0.54	2.80	2.10	4.10
Grinding	Heat Cure Resin	14.46	0.88	14.50	12.80	15.90
	Microwave Cure Resin	12.00	1.15	12.10	9.80	13.90
	Self Cure Resin	6.35	0.76	6.30	5.10	7.90
Sand Blasting	Heat Cure Resin	11.31	0.97	11.40	9.80	12.80
	Microwave Cure Resin	14.39	0.78	14.45	12.90	15.90
	Self Cure Resin	7.56	0.77	7.70	6.10	8.90

TABLE III: Results of the ANOVA test for bond strength. ** denotes a significant difference.

Source	df	Sum of Squares (SS*)	Mean SS*	F	P-Value
Treatment	2	1392.30	696.10	560.31	< 0.001**
Curing	2	6736.80	3368.40	2711.20	< 0.001**
Treatment *Curing	4	321.60	80.40	64.70	< 0.001**
Error	207	257.20	1.20	---	---
Total	215	8707.80	---	---	---

TABLE IV: Results of the ANOVA test for tensile strength. ** denotes a significant difference.

Source	df	Sum of Squares (SS*)	Mean SS*	F	P-Value
Treatment	2	550.50	275.25	349.53	< 0.001**
Curing	2	2027.04	1013.52	1287.02	< 0.001**
Treatment*Curing	4	372.57	93.14	118.28	< 0.001**
Error	207	163.01	0.79	---	---
Total	215	3113.13	---	---	---

In order to find out among which pair of groups and curing there exists a significant difference with respect to the mean bond strength and mean tensile strength, multiple comparisons with post-hoc test using Bonferroni method was done. The most important factor influencing bond strength is the curing followed by surface treatment. We observe that sandblasting group yields a higher bond strength and tensile strength compared to the other two groups. It is followed by grinding group. The least bond strength and tensile strength were recorded in the control group.

The difference in mean bond strength and tensile strength between the different groups was found to be statistically significant (P < 0.001). Heat cure resin yields a higher mean bond strength and tensile strength followed by microwave cure resin and self cure resin respectively. The difference in mean bond strength and tensile strength between them is found to be statistically significant (P < 0.001).

DISCUSSION

All bond strength results attained values comparable with the criteria in IS0-3336 of 31 MPa for bond strength test[5]. In fact, the free surface energy of the newly sandblasted resin surface created by sandblasting with Alumina (Al 203) is undoubtedly higher than that of the untreated surface, which may be a reason why roughening improves bonding. In addition, wetting the acrylic resin surface with methyl methacrylate monomer was reported to increase the bond strength between resin polymer.[11]Cohesive failure could also explain as evidence that monomer containing the greater amount of cross-linking agent facilitated the infiltration of polymerizable materials from the denture base into the undercuts and improved the formation of a more extensive interwoven polymer network. The type of failure also needs to be considered because fractures may occur in the denture tooth before occurring at the interface between tooth and denture base. A previous report showed that most dentures failed as a result of denture tooth fracture. This implies that the value of fracture load may have some degrees of relationship to the internal strength of the tooth. It was therefore no surprise that no statistically significant differences in the fracture load between the two brands of acrylic teeth tested in this study were discovered.[12]

Within the limitations of this study design and without consideration of thermocycling effect and cyclic loading as well as human chewing patterns, specimens in this in-vitro study were prepared and loaded to simulate clinical conditions according to the ANSI /ADA Specification No. 15. The tooth denture base bond was considered satisfactorily strong in this specification only if debonding does not occur at the tooth denture base interface and if the denture base material remains firmly attached to the tooth. Using this criterion, all denture teeth tested in this study polymerized with either heat or microwave polymerization bonded satisfactorily. Nevertheless, the microwave polymerized subgroups exhibited lower bond strengths, indicating that the method of polymerization influenced tooth-to-base bond strength. In fact, microwave polymerization was reported to have uncontrolled temperature rise, causing the denture base components to heat above the boiling point of the monomer and resulting in the formation of pores.[13] Thus, increased number of pores, which reduces denture base strength, may generally be found after microwave polymerization compared with heat processing, especially in the thicker part of the denture. The thickness of the test specimen bar used in the study may imply that formation of pores is a likely explanation for the bond failure after microwave polymerization.[14] This finding is of clinical importance because the thickness of the denture base material in the tooth bearing areas might promote pore formation. Although the most likely mechanism for the increase in bonding strength of denture tooth to denture base is related to the result of tooth surface treatment, the effects of strength of denture tooth and denture base material cannot be eliminated.

Future experiments should be performed to investigate the effects of the internal strengths of both the denture tooth and base material on the mechanism of debonding .[15]

There is a wide variation in the materials tested and the methodology used for constructing and testing the samples for bond strength. Contamination with wax seems to be the major cause for bond failure between teeth and denture base resins. Contamination with tin foil substitute reduced the bond strength values in some studies whereas there was no decrease in one study[16]. Application of adhesive bonding agents or chemicals like dichloromethane to acrylic teeth has demonstrated an improvement in the bond strength values. Modification of the ridge lap area of the acrylic resin teeth demonstrated an increase in bond strength, whereas some other studies showed no obvious advantage.

There was no difference in the bond strengths in hydrated or unhydrated specimens and thermocycling was found to reduce the bond strength[17]. Heat activated resins produced a higher bond strength than the microwave activated, visible light-cure, pour type or self cure acrylic resins. It has been recommended that a bonding agent should be applied when using a visible light cure resin to enhance bond strength.

Commercially, vast number of teeth and denture base resins are available for denture construction [15]. However there is usually little or no mention of bond strength or compatibility of acrylic teeth to the denture base resins by the manufacturers. The selection of more compatible combinations of acrylic teeth and denture base resins may reduce the number of prosthesis failures and the resultant repairs.

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